# Characterization of Salmonid Over-Wintering Habitat within Seasonally Flooded Land on the Carnation Creek Flood-Plain

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## ABSTRACT

Seasonally flooded land (ephemeral swamps and intermittent tributaries) located on the floodplain of a west coast Vancouver Island stream (Carnation Creek) was examined for two winters. Seven distinct map units were identified by discriminant analysis, based on environmental and biotic factors. These seven map units were further grouped into three habitat units based on their ability to support over-wintering coho (*Oncorhynchus kisutch* ) and trout (*Salmo gairdneri* and *S. clarki clarki*). The use of these habitat units to identify salmonid off-stream winter habitat was shown to be valid for the watershed in which it was developed.

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Brown, T.G. 1985. The role of abandoned channels as over-wintering habitat for juvenile salmonids. M.Sc. thesis. University of British Columbia, Vancouver, B.C. 134 p.

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# 1 INTRODUCTION

British Columbia's coastal watershed support both an abundant fishery and a productive forest industry. However, the aquatic and terrestrial components of a watershed are closely linked. The forest plays an important role in regulating hydrologic, trophic, and biotic systems, which ultimately govern fish production by altering quantity, quality, and use of fish habitat. Forestry activities on west coast alluvial flood-plains have the potential of altering juvenile salmonid over-wintering habitat associated with small ephemeral swamps and intermittent tributaries (off-stream habitat). Forest land managers must be able to identify such areas of potential conflict between forestry and fisheries resource options.

Off-stream habitat has never been clearly defined or characterized and our ability to identify it is poor. No clear delineation between flooded lands and winter fish habitat, or between summer rearing habitat and winter habitat, has been made. These off-stream areas are often ephemeral, lacking standing water in summer but retaining adequate water levels in winter to support fish. Thus, summer surveys based solely on the presence of adequate water levels would fail to identify many potential winter rearing sites.

A freshwater residence of at least 1 year is required for completion of the coho salmon (*Oncorhynchus kisutch* ) life cycle (Fig. 1). In winter within the Carnation Creek watershed (Fig. 2), coho juveniles occupy

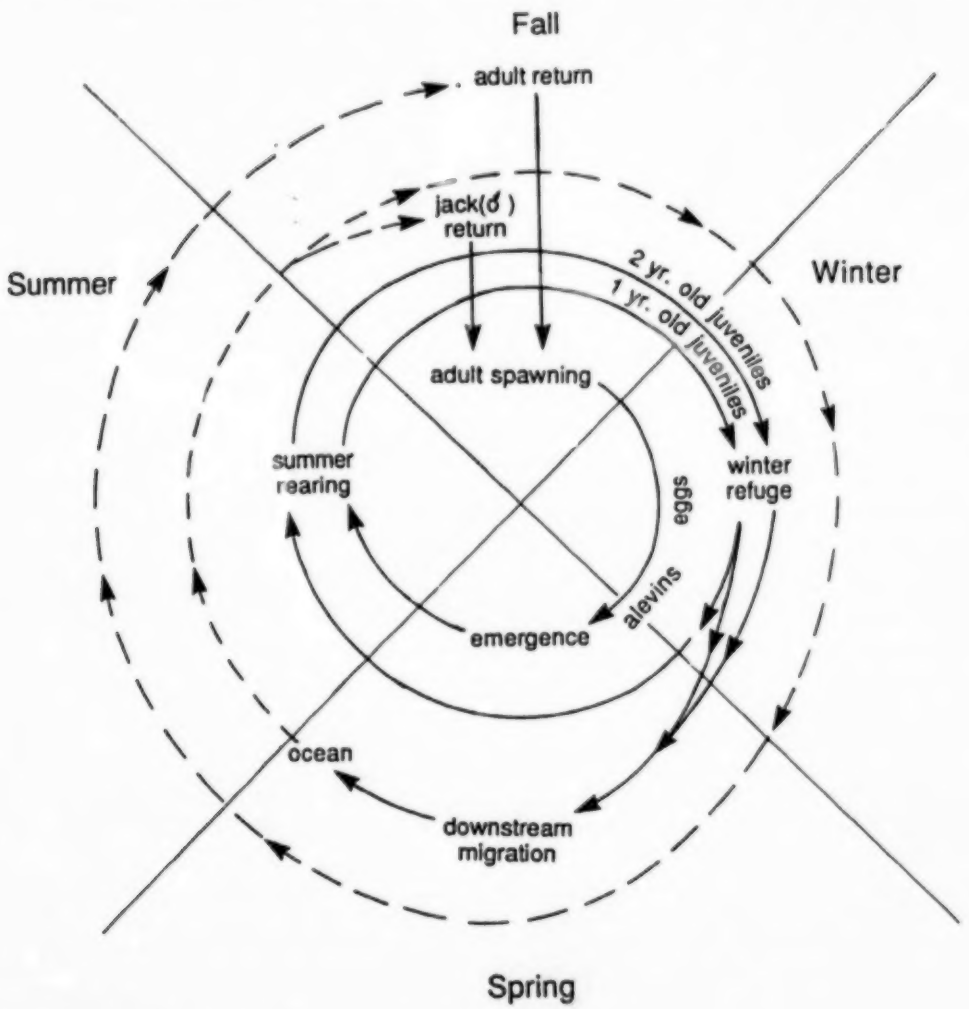


FIGURE 1. A generalized life cycle of the coho salmon (*Oncorhynchus kisutch* ).

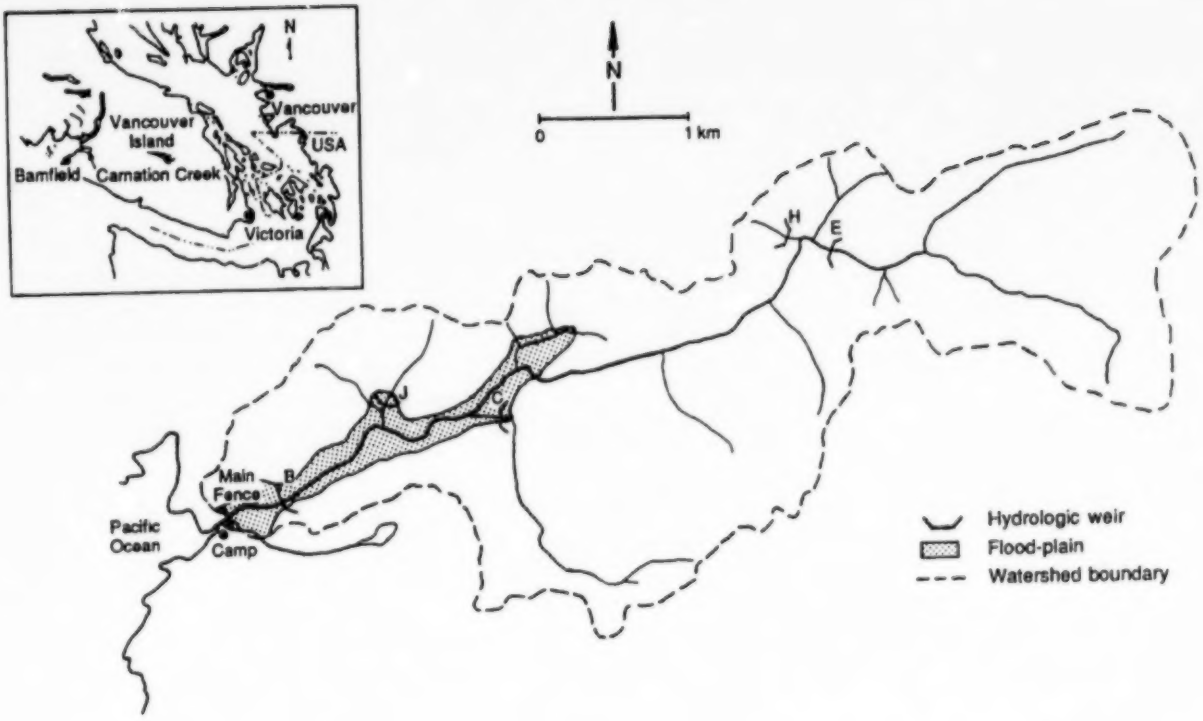


FIGURE 2. Map of Carnation Creek watershed showing locations of tributaries, hydrographic weirs, fish counting fence, and flood-plain.

both main-stream habitat (side pools, undercut banks, and debris piles) and off-stream habitat (ephemeral swamps and intermittent tributaries) (Bustard and Narver 1975; Tschaplinski and Hartman 1983; Forward 1984; Brown 1985). Seasonal movement of coho and use of winter off-stream habitat in other Pacific Northwest watersheds is also well documented (Skeesick 1970; Mason 1976; Peterson 1980; Cederholm and Scarlett 1981; Scarlett and Cederholm 1983). Off-stream habitat may be used by juvenile coho as a refuge from adverse conditions within the main-stream, such as high discharge and large volumes of suspended sediment (Skeesick 1970). "Trout" (rainbow, *Salmo gairdneri* and cutthroat, *S. clarki clarki*) also inhabit some of the off-stream sites during the winter (Bustard and Narver 1975; Tschaplinski and Hartman 1983; Hartman and Brown 1987).

The value of winter off-stream ponds, swamps, and tributaries for coho production may have been highly underestimated historically. Peterson and Reid (1983) estimate that 20-25% of the Clearwater River's total smolt yield came from "wall based channels" removed from the main river channel. Within the Carnation Creek watershed, more than 15-25% of the total smolt yield came from off-stream sites and as much as 15% of the total smolt yield over-wintered within sites devoid of standing water during summer (Brown 1985). The possibility that off-stream habitat may provide an alternative winter survival strategy must also be considered (Brown 1985).

The purpose of this study is provide watershed managers with a guide to recognizing potential coho and trout winter habitat. Before proper management of any habitat can take place, it must first be identified. In characterizing the flooded areas located on the Carnation Creek flood-plain, this study used botanic, pedologic and hydrologic parameters to develop habitat unit descriptions.

The basic terms to describe the relationship between components of the flood-plain and their hydrology are:

1. Flood-plain - defined as a valley bottom land form deposited by running water, which is at least occasionally inundated by water from the stream (Cordes 1972).
2. Flooded land - those areas of the flood-plain (not including the main stream channel) covered by water or containing numerous pockets of standing water during winter base flow.
3. Ephemeral - those sites (sloughs, swamps, temporary channels) that contain standing water during winter base flow, but are completely dry in summer.
4. Intermittent - those sites (generally first-order tributaries) containing visibly flowing water all winter but only isolated pools during the driest summer month.

The basic terms to describe the relationship between salmonids and their habitat are:

1. Off-stream - those sites removed from the main-stream, including all tributaries, swamps, and flooded lands.
2. Potential habitat - areas lacking coho but capable of supporting them if access was provided.
3. Winter period - generally extends from late October to early May. It starts with the first fall storms (coho movement into off-stream sites) and ends when the ponds and swamps become dry (cessation of coho movement out of the off-stream sites).

## 2 STUDY AREA

Carnation Creek is a small stream flowing into Barkley Sound on the west coast of Vancouver Island (Fig. 2). The Carnation Creek Watershed Project was initiated in 1970 to investigate forestry-fisheries interactions and stream processes. Numerous descriptions of the project and the watershed are available (Narver and Chamberlin 1976; Symons 1978; Hartman 1981; Hartman 1982).

Carnation Creek was chosen as a site for investigation of off-stream winter habitat for several reasons. First, experiments conducted within the Carnation Creek watershed could use facilities, equipment, and support staff not readily available on other streams. Second, a long history of biological and physical data collection (15 years), including before-harvest information, aided in interpretation of data obtained for this paper. Third, Carnation Creek has a sizeable flood-plain and is subjected to extreme flooding in response to winter storms. Fourth, use of off-stream sites by over-wintering salmonids has been documented by others (Bustard and Narver 1975; Tschaplinski and Hartman 1983).

### 2.1 Physical Features

Carnation Creek drains an area of 10 $km^2$, has a total length of 7.8 km, and an accessible length for anadromous fish of approximately 3.2 km (Scrivener 1982). The stream flows from east to west and is flanked by steep north- and south-facing slopes. The terrain is generally rugged with a maximum elevation of 880 m (Hetherington 1982).

The area of interest for this study was the flood-plain located in the lower half of the watershed (Fig. 3). The flood-plain forms a narrow strip 3000 m long, ranges from 50 m to 300 m wide, covers an area of approximately 50 ha (5% of total watershed), and is bounded by steep slopes (often greater than 60%) on either side. It drops 21 m to sea level in the lower 3.2 km and has an average slope of 0.7%.

The flood-plain contains no terraces and during storm flow conditions is often flooded for much of its length. A general description of Sitka spruce flood-plains similar to the Carnation Creek flood-plain

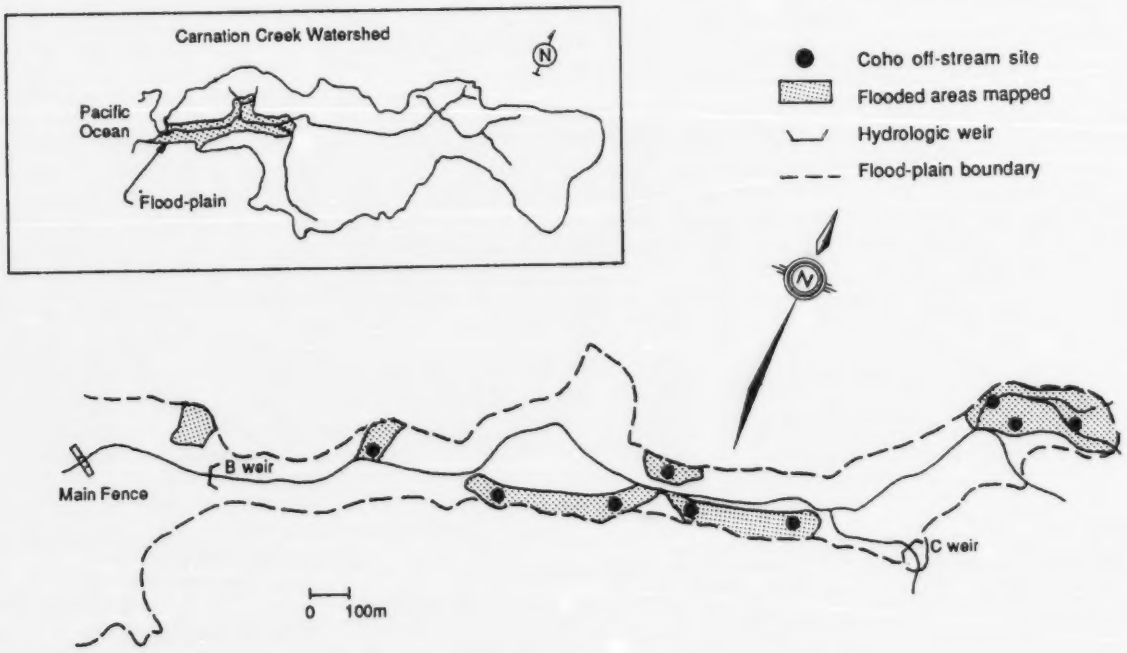


FIGURE 3. Map of Carnation Creek flood-plain showing locations of tributaries, hydrographic weirs, fish counting fence, flooded areas mapped, and salmonid over-wintering sites.

can be found in Cordes (1972). Numerous old channels exist throughout the valley bottom and these are often the first sites to receive storm flow from the main channel. Where these old channels border the base of the valley walls, seepage water from up-slope positions can maintain adequate winter water levels to support over-wintering fish populations. A description of the physical characteristics and geomorphological development of small tributary systems similar to those located on the Carnation Creek flood-plain can be found in Peterson and Reid (1983).

### 2.2 Soils

The soils of Carnation Creek have been described by Oswald (1973). These coarse-textured soils are of volcanic origin. The parent material of soils found on the flood-plain, however, are of recent alluvium overlying gravel deposits as much as 4 m deep (Scrivener and Brownlee 1980). The old channel scars collect vertical accretion material (fines and fine sand carried by slow moving flood waters), which covers the coarse lateral accretion material (coarse sands and gravels left in channel scars)during periods of active flooding (Happ *et al.* 1940). The fine vertical accretions combined with organic materials often produce muck blankets as much as 1 m deep. These materials are stabilized by semi-aquatic vegetation, and organic soil types are representative of most of the small ephemeral swamps.

### 2.3 Climate

The area has a mild, wet winter with frequent frontal storms producing rapid increases in stream flow. Slightly over 75% of the precipitation occurs from October to March (Hetherington 1982) and less than 5% of the precipitation is in the form of snow (Scrivener and Brownlee 1980). Total precipitation ranges from 230 to 380 cm annually. Annual water temperatures recorded at B weir (location indicated in Fig. 3) range from 1 to 18°C (Hartman 1982).

### 2.4 Stream Discharge

Stream discharge is closely correlated to precipitation, and this stream is considered to be "flashy" in nature (Hetherington 1982). Minimum flows generally occur in July or August (lowest recorded flow was 0.017 $m^3$/sec) and the two highest recorded flows were in January (50 $m^3$/sec on January 28, 1982; 65 $m^3$/sec on January 4, 1984)[1].

### 2.5 Vegetation

Before harvest, the dominant vegetation consisted of a dense overstory of western hemlock (*Tsuga heterophylla*, amabilis fir (*Abies amabilis* ), and western redcedar (*Thuja plicata* ). A few isolated Douglas-fir (*Pseudotsuga menziesii* ) grew on the well-drained southern slopes and Sitka spruce (*Picea sitchensis* ) was sparsely scattered throughout the alluvial flood-plain. Red alder (*Alnus rubra* ) and big leaf maple (*Acer macrophyllum* ) could be found bordering the main-stream at various locations, especially in the lower sections. The vegetation prior to logging has been described by Oswald (1973).

After harvest, the majority of the flood-plain was planted with Sitka spruce and western redcedar. Natural regeneration of western hemlock and amabilis fir has occurred. The rapid growth of salmonberry (*Rubus spectabilis* ) and red alder had created a serious forest regeneration problem over much of the flood-plain. The application of the herbicide glyphosate (Roundup) during September 1984 has eliminated much of the brush competition.

### 2.6 Ecosystem Classification

A general description of British Columbia's west coast has been given by Krajina (1969) using the biogeoclimatic approach. A detailed description of climate, vegetation, and zonal soils is given by Klinka *et al.* (1979, 1984). The lower elevations (below 150 m) lie within the windward submontane

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[1] Carnation Creek Working Group. 1985. Data records. Can. Dep. Fish. Oceans, Pac. Biol. Stn., Nanaimo, B.C. Unpublished data.

variant of the wetter coastal western hemlock subzone (CWHb1). The remainder of the watershed (above 150 m) falls within the windward montane variant of the wetter coastal western hemlock subzone (CWHb2).

### 2.7 Fisheries Resource

From 1970 to 1982 Carnation Creek has supported an annual mean run of 2014 chum salmon (*Oncorhynchus keta* ) and 251 coho salmon (*O. kisutch* ). Anadromous trout are few in number (less than 20 per year) and include both steelhead trout (*Salmo gairdneri* ) and sea-run cutthroat trout (*S. clarki clarki* ). The occasional pink (*O. gorbuscha* ), sockeye (*O. nerka* ), and chinook (*O. tshawytscha* ) have been observed, but they are not present most years (Andersen 1983, 1984).

The distribution of resident trout within the lower 3.2 km is uneven. Trout account for a higher proportion of the fish population in the upper 1200 m and a lower proportion in the lower 2000 m (B. C. Andersen, pers. comm., 1986, Pac. Biolog. Stn., Nanaimo, B.C.). Calculations made using 1982 data from a Carnation Creek report (Andersen 1984) indicate the late summer salmonid population consisted of 7557 coho juveniles, 1456 rainbow trout, and 205 cutthroat trout. Two sculpin species also inhabit the stream, prickly sculpin (*Cottus asper* ) and Aleutian sculpin (*C. aleuticus* ) (Ringstad 1982).

### 2.8 Logging Operations

Road construction within the Carnation Creek watershed took place from 1974 to 1978 with 22 km of road being constructed during the winter months (MacMillan Bloedel Ltd. 1979). From 1975 to 1981, 388 ha (41%) of the watershed was clearcut in 12 settings (Dryburgh 1982). Harvesting was conducted from September to May and total volume within the settings ranged from 438 $m^3$/ha to 1098 $m^3$/ha (MacMillan Bloedel Ltd. 1979). Yarding was done by mobile high lead spar or by grapple yarder. Approximately 25% of the volume removed was by direct loading from the road rights-of-way (Dryburgh 1982).

To date, all trees on the flood-plain have been harvested, but no roads have been constructed on the flood-plain. No special consideration such as leave-strips were given to any of the off-stream sites examined in this study. Although much of the watershed was treated by broadcast burning, the alluvial flats received patchy burns mainly because of their continually high moisture status. All off-stream sites examined during this study were harvested between March 1976 and March 1979.

# 3 METHODS

## 3.1 Method of Site Selection

During the months of November and December 1982, the Carnation Creek flood-plain was examined in detail. All areas of flooded land were noted and limits of standing water were marked with survey tape. Six distinct flooded areas were marked and surveyed during the summer of 1983, using a 5-m grid pattern. Maps of all six flooded areas were constructed to a scale of 1:500 (see Figures A10-A15).

From December 1982 to January 1983, all flooded lands were examined for trout and juvenile coho presence. Minnow traps (Plate 1) were used to capture fish. Each trap was baited with a spoonful of canned herring, contained in a perforated plastic sandwich bag and left for 24 hr to attract fish. All traps were placed with openings parallel to the direction of any apparent flow and required a depth of 8 cm before openings were accessible. Traps were scattered throughout the sites independent of cover or substrate types. A series of 10-25 minnow traps were placed within each of the six flooded ar[illegible]. If no fish were obtained after completion of three over-night trapping series, the area was des[illegible]d as non-habitat. If fish were obtained, the traps were moved to new locations within that area until the geographical limits of coho distribution were established. Based on fish presence and obvious natural physical features within the six flooded areas examined, nine off-stream over-wintering sites and two non-habitat sites were delineated (Fig. 3). Each of these sites was examined for general topographic and hydrologic characteristics.

PLATE 1. Placement of a baited minnow trap within an ephemeral muck swamp site.

These sites were named on the basis of the following system. A symbol L or R indicates on which side of the stream the off-stream site can be found (left or right, looking downstream). A number represents the distance in metres from the mouth of Carnation Creek (mean summer high-tide mark) to the confluence of a given site's outlet with the main-stream. A descriptive term was added to clarify location of sites within the two tributaries. Thus, L1600 m upper would indicate an off-stream site located on the left side of the stream, within the upper section of a tributary system, whose confluence with the main-stream is 1600 m upstream from the stream's mouth.

## 3.2 Method of Salmonid Habitat Characterization

### 3.2.1 Theory

Forty sample plots were established within the six flooded areas located on the Carnation Creek flood-plain. Each plot was 10 $m^2$ (2 x 5 m) and was placed within an area uniform in vegetative and surface characteristics. Plots were selected to represent a potential map unit; their location was not chosen randomly. All plots were examined for debris, vegetation, surface characteristics, depth to water table, and presence of fish.

Plots were analyzed for each biotic or environmental feature, and those plots considered to have similar features were arranged into groups (discriminant analysis). These groupings of plots were then summarized for all distinctive features, and a set of map units was obtained. Those features characteristic of a given map unit were used to name and describe that unit, and also to delineate it. Maps of all off-stream winter flooded land were then prepared, based on the map units established (Fig. A10-A15).

Once map units were established, they were grouped into habitat units for potential management use . This interpretive classification was based on the presence of trout and coho within the 40 plots. Characteristics common to these units were used to describe and identify off-stream salmonid habitat.

### 3.2.2 Vegetative features

The vegetation data taken for each plot included a species list (Table A11) and an estimation of the species significance according to the Domin-Krajina cover-abundance scale (Mueller-Dombois and Ellenberg 1974, p. 62). The percentage cover for each stratum (vertical layering) was also recorded. The field methods used, including detailed listings of descriptive criteria, are those given in Describing Ecosystems in the Field (Walmsley *et al.* 1980); and the methods of analysis are those described in Aims and Methods of Vegetation Ecology (Mueller-Dombois and Ellenberg 1974). A program to execute tabular comparison, "VTab" (Emanuel and Wong 1983), and an ordination program "Ordiflex" (Gauch 1977) were used to aid in establishing plant associations. Plant species characteristic of each plant association were identified using criteria established by Inselberg *et al.* (1982). No attempt was made to classify these early successional associations (5-10 years after harvest) within the existing ecological classification system used by the B.C. Ministry Forests for the Vancouver Forest Region (Klinka *et al.* 1980; Inselberg *et al.* 1982).

### 3.2.3 Surface features

For each of the 40 plots, five randomly selected subsamples of the top 10 cm of soil were pooled into one composite sample. This composite sample was then fractioned into size classes, according to the U.S. Department of Agriculture soil particle size classification, by dry sieving (Lavkulich 1977, p. 178). The percentage of organic material for each size class was obtained by ashing the soil samples. A slight modification to the method described in Lavkulich (1977) included the gradual raising and lowering of furnace temperature from room temperature to 480°C over a 12-hr period, instead of the placing of samples into a pre-heated oven for 1 hr at 300°C and 4 hr at 480°C.

### 3.2.4 Water table depth

Water table wells were used to obtain a measure of water table depth relative to the surface of the plot. Water levels were recorded during the last week of every month for 14 months. At least 3 days without appreciable rain was required before measurements could be taken. This requirement delayed the May 1984 measurements until June 3. Water table wells were placed in the plots to best represent the average water table depth of the entire plot. Although the majority of plots were level, the few plots that were micromounded had a slight variation in water level over their surface.

### 3.2.5 Fish presence and abundance

The presence and abundance of two fish groups, coho and trout (species differentiation of any live trout less than 80 mm in length was not reliable), were recorded for each of the 40 plots on 10 separate sampling dates. Eight of the sampling dates represented the winter period, while the other two represented the summer period (summer sampling was confined to the intermittent tributaries). In those instances where a trap was not placed directly within a plot, the trap nearest to the plot and still within the same map unit was treated as being representative of that plot.

## 3.3 Method of Testing Habitat Units

To test validity of the interpretive classification developed for salmonid off-stream over-wintering habitat, the classification was applied to the Carnation Creek flood-plain. It was assumed that if it was valid, there would be a good relationship between the number of coho juveniles over-wintering within a site and the area within that site delineated as coho habitat, as well as a good relationship between the number of trout and the area within that site delineated as trout habitat.

For each of the 11 winter flooded sites, the area of each of the habitat units was obtained by summation of the appropriate map unit areas (indicated on the six maps of winter flooded land; Fig. A10-A15). A hand planimeter was used to estimate all areas.

Estimates of coho population size within all off-stream sites were obtained by mark-recapture method, based on the formula (Begon 1979):

$$N = r\,(n + 1) / (m + 1) \qquad (1)$$

where N is the estimate of population size, r is the number of marks at risk, n is the total number of juveniles captured, and m is the total number of marks recovered. This estimate has been named the "simple Peterson estimate" and uses "Bailey's correction" to give a less biased estimate (Begon 1979). Estimates of trout population size were based on the capture ratio of trout to coho.

Both initial capture and recapture was by minnow traps (Plate 1), and a trapping density of greater than one trap per 15 $m^2$ of water surface was maintained. Coho were marked (Plate 2) by a cold branding technique (Everest and Edmundson 1967).

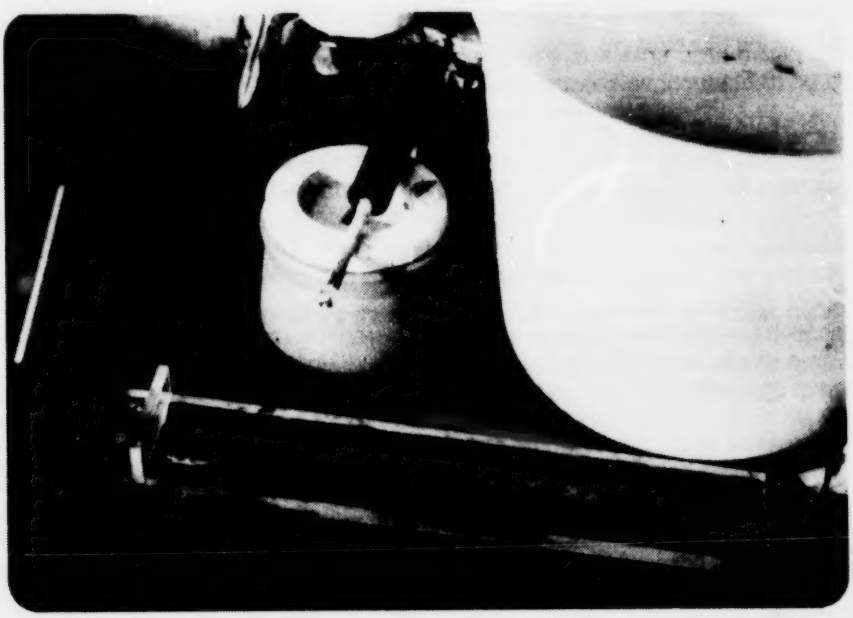

PLATE 2. Equipment used to mark (cold brand) juvenile coho. Includes: 1) acetone and dry-ice coolant in thermos, 2) silver tipped brand with wooden handle, 3) anesthetizing bucket, and 4) measuring board.

# 4 RESULTS

## 4.1 General Features of Over-Wintering Sites

The total area of land flooded during winter base flow (six areas mapped; see Fig. 3) was 12807 $m^2$, while the area of the sites supporting salmonids was 9845 $m^2$ (Table A1). These values cannot be directly equated to wetted area, because raised mounds (hummocks) existed throughout the flooded lands. All discharge levels given in Table A1 are rough estimates of discharge recorded at a hydrologic weir located at approximately 350 m (B weir).

One flooded area (R250 m) did not support a salmonid population. Fish access was restricted to periods of extreme flooding (> 35 $m^3$/sec at B weir). This area did flood during both winters of study, but only after coho winter distribution was established. Water levels within the R250 m area respond very quickly to climatic conditions. It is the first area to go completely dry in February, well before coho out migration begins and during January 1984 only a few isolated shallow pools covered with thick ice remained. If fish were present within this area, it is doubtful they could survive.

## 4.2 Salmonid Habitat Characterization

### 4.2.1 Plant associations

Four plant species groupings (plant associations) were identified by both reciprocal averaging ordination (Fig. A1) and tabular comparison (Table A12). The characteristic species (plant species whose distribution is exclusively, selectively, or preferentially associated with a given grouping) and constant species (plant species dominant within a given grouping but also dominant in all or nearly all other groupings) for these plant associations are listed in Table A2.

### 4.2.2 Vertical spacing (strata)

The percentage cover by stratum was estimated for each of the 40 plots. The strata categories (vertical spacing of vegetation) were similar to those indicated by Walmsley *et al.* (1980). These include:

1. trees (A1, A2, A3 strata)
2. tall shrubs (B1 stratum), woody plants 2-10 m in height
3. low shrubs (B2 stratum), woody plants < 2 m in height
4. herbs (C stratum), herbaceous species
5. mosses (D stratum)

No vegetation greater than 10 m in height (A stratum) was recorded on any of the plots and no plot had greater than 5% total shrubs (B1 + B2). The majority of vegetation was in the C and D strata (Fig. A2). Four groupings of plots based on vertical spacing of the plant communities were identified (Table A3).

### 4.2.3 Woody debris

All locations within the off-stream areas covered by more than 90% woody debris were mapped as a single entity (Table A4, woody debris). No plots were established and no further analysis was performed on this map unit. Piles of woody debris may, in fact, overlie each of the other map units, but recognition of these map units was impossible. No attempt was made to relate fish presence or abundance to off-stream woody debris.

Woody debris, consisting mainly of intermediate-sized material (limbs, bark, and broken logs), accumulated at the base of the valley walls during yarding operations. This debris aggregated into piles, depending on the site's flooding characteristics. All plots chosen to represent the other map units were covered by less than 70% woody debris.

### 4.2.4 Surface soil

The 40 plots were divided into two groups (Fig. A3) based on percent organic material and percent of soil sample smaller than fine sand (0.25 mm in diameter). All plots representing group1

(Table A5) were located within the three intermittent tributary sites and were subjected to high discharge during winter. Organic and small inorganic soil particles were washed out of these plots, leaving only coarse sands and gravels low in organic material.

Thirty of 34, group 2 surface samples (Table A5), were classified as organic soils (> 30% organic by weight, Canada Soil Survey Committee 1978). Only four plots had < 30% organic material by weight. One of these plots was partially scoured to clay and three of the plots had received fresh vertical accretions, which covered the original organic substrate (high percentage of fine sands, low percentage of organic material).

#### 4.2.5 Water levels

Four groupings of plots were identified based on differences in summer (June - Sept.) and winter (Oct. - March) mean water levels (Fig. A4, Table A6). Two of the groupings correspond to plots that maintained constant seasonal water levels (< 10 cm change from winter to summer). These two groupings could be separated by their relative height of standing water: if mean summer water level was maintained above 8 cm, the plot was considered to be constantly flooded; if mean winter water level was less than 8 cm, the plot was considered to represent a seepage site.

The remaining two groupings correspond to plots that have variable seasonal water levels (> 10 cm change from winter to summer). These plots tended to be flooded in winter and dry in summer. The two groupings were distinguished by their relative summer water levels: if mean summer water level fell below -25 cm, the plot was considered representative of a flooded meadow; if mean summer water level was maintained above -25 cm, the plot was considered to be representative of a "muck-swamp".

#### 4.2.6 Map units

A summary of the various plot groupings (discriminant analysis based on all environment and biotic factors) permitted recognition of seven distinct map units (Table A7). Each of these map units was described (Table A8) and identified (see maps, Figures A10-A15) according to the characteristics unique to each plot grouping best representing that map unit. No single environmental or biotic feature could be used to distinguish all seven map units.

#### 4.2.7 Habitat units

The map units described above were further grouped into habitat units based on their ability to support over-wintering coho and trout. Map unit 1 was ascertained to be trout habitat (Fig. A5, top), while map units 1, 2, and 3 consistently supported over-wintering coho and were therefore considered to be important as coho habitat (Fig. A5, bottom). These three map units maintained the most constant and deepest water levels over the winter period (Fig. A6). Although coho were trapped in map units 6 (2/6 plots) and 5 (1/6 plots), the catch was sparse and these map units were considered non-habitat. Map units 5 and 6 were subject to both an early spring and a mid-winter drop in water level (Fig. A6). The mid-winter drop in water level may have been the result of freezing. Map unit 4 never maintained water levels adequate to support over-wintering fish.

Map unit 1 must be considered as coho summer habitat as well as winter habitat, because coho were captured within this unit during September (5/6 plots). This map unit maintained a constant water level throughout the year, but lacked a visible flow during much of the summer. The three habitat units identified were described according to the characteristics of the map units composing them (Table A9).

### 4.3 Application of Habitat Units

Coho were not distributed equally throughout the flooded land (Table A10) and a poor correlation ($r < .01$) was evident between total flooded area for each site and juvenile coho over-wintering population size (Fig. A7, top). A significant correlation existed between the area delineated as coho winter habitat and coho over-wintering population size (Fig. A7, bottom, $r = .96$, $P < .001$). This illustrates the importance of identifying coho winter habitat rather than simply using flooded land as an indication of over-wintering coho presence.

Trout were not distributed evenly throughout the flooded lands (Table A10). Three intermittent

tributary sites supported over 95% of the total trout population over-wintering off-stream. Almost all of habitat unit 1 was located within these sites. No correlation existed between number of trout and either total flooded area for each site or area of coho winter habitat (habitat unit 1 + 2; Fig. A8, top). A significant correlation ($r = 0.98$, $P < .001$), however, did exist between number of trout using a site and area delineated as habitat unit 1 (Fig. A8, bottom).

# 5 DISCUSSION

## 5.1 General Features of Over-Wintering Sites

### 5.1.1 Common features

Three sites were considered to be intermittent tributaries and six sites were named ephemeral swamps. Eight of the nine sites closely paralleled the valley walls for the majority of their length, and seepage from upland surfaces was a major contributor to winter water levels. The majority of ephemeral swamp sites (5/6) were formed within abandoned main-stream channels. Access to all sites supporting over-wintering juvenile salmonids was available at flows of less than 11 $m^3$/sec (at B weir).

Semi-aquatic vegetation was common to all flooded areas. A visual comparison of winter flooded land to surrounding higher land indicated an obvious lack of shrubs and trees rooted within the wet areas. Surface substrate within the ephemeral swamps consisted of blankets or veneers of muck, overlying gravel left in the abandoned channels. Within the intermittent tributaries, exposed sand and gravel surfaces dominated.

### 5.1.2 Surface area

The flood-plain covers an area of approximately 50 ha, of which 3 ha is main channel (estimate of area from bank to bank, from Andersen 1984). The off-stream area flooded during winter base flow (estimate from area maps, see Figures A10-A15) is 1.3 ha. Only 0.98 ha of this off-stream flooded land was inhabited by salmonid juveniles during the winter months.

### 5.1.3 Evolution of off-stream sites

Descriptions of fluvial processes have been written by several authors (Happ *et al.* 1940; Wolman and Leopold 1957) and the nature of flooding on a flood-plain has been modelled by Lewis and Hughes (1978). Good descriptions of general processes occurring on west coast Sitka spruce alluvial flood-plains, similar to that of Carnation Creek's flood-plain, were written by Cordes (1972) and Peterson and Reid (1983). The possible evolution of off-stream ephemeral swamp sites, as hypothesized in Figure A9, is based upon processes described by these authors and on consideration of features common to the sites observed during the course of this study.

Lateral accretion and course channel material left within the abandoned channels is covered by fine vertical accretions deposited from the flood waters and fines displaced from the valley walls. Growth of semi-aquatic vegetation stabilizes the fines and permits accumulation of a blanket of muck soil. Depending on flooding characteristics and the relationship to upslope seepage, scour over time may create narrow, deep channels within the muck blankets. These sites could eventually fill in and support tree growth, or scour to the original sand and gravel stream bed left within the abandoned channels.

## 5.2 Salmonid Habitat Characterization

One of the objectives of this study was to characterize coho and trout off-stream winter habitat within the early successional ecosystems located on the Carnation Creek flood-plain. The flooded lands were described and mapped according to easily recognizable environmental and biotic factors. Seven map units were delineated. A combination of factors must be used to identify a given mapping unit, because no single environmental or biotic factor was unique to each of the seven units.

Three habitat units were established, based on the ability of the mapping units to support over-wintering salmonids. The development of habitat units should assist watershed managers in differentiating salmonid habitat from flooded non-habitat during the winter, and in recognizing potential salmonid habitat during summer when most sites are dry. Trout did not over-winter within habitat occupied by coho. They inhabited intermittent tributaries (habitat unit 1), while coho occupied both intermittent tributaries and ephemeral swamps (habitat unit 1 and 2).

The natural successional trend for the flood-plain should end with the development of a climatic climax western hemlock and western redcedar forest (Klinka *et al.* 1979). The flood-plain has been planted with western redcedar, western hemlock, and Sitka spruce (MacMillan Bloedel Ltd. 1979), but

will not reach a climatic climax state before the next harvest. The small ephemeral swamps and intermittent tributaries located on the flood-plain may represent an edaphic climax, as some sites existed in a similar condition prior to harvest (Bustard and Narver 1975; Tschaplinski and Hartman 1983).

Caution in applying the habitat and map units developed for the Carnation Creek watershed to other watersheds and successional stages must be emphasized. Few west coast streams have as extensive a flood-plain and, as the Carnation Creek watershed lacks major storage elements (lakes and ponds), its flooding characteristics might not apply to other systems. Although ephemeral swamps and tributaries may be considered an edaphic climax stage, harvesting has eliminated the canopy and altered water levels on the flood-plain (Hetherington 1982; Hartman and Holtby 1982). This will likely alter the presence, vigour, and significance of the plant species forming the various plant associations.

### 5.3 Validity of Habitat Units

In identifying coho or trout over-wintering habitat, care must be taken to use the characteristics that correctly indicate each species' winter habitat, rather than simply defining all flooded land as habitat. Coho and trout showed marked differences in use of off-stream winter habitat (Hartman and Brown 1987). Trout over-wintered only within the sand and gravel bottomed, intermittent tributaries; while coho used these tributaries as well as muck-bottomed, ephemeral swamp sites.

The development of habitat units (an interpretive classification) was accomplished with the specific purpose of aiding watershed managers in identifying potential salmonid winter habitat on marginally flooded lands. After this interpretive classification was applied to the 11 winter flooded sites located on the early successional flood-plain of Carnation Creek, a good relationship was found between population size and area delineated as habitat, for both coho and trout. It was therefore concluded that the use of the three habitat units for identifying salmonid winter habitat was valid for the watershed in which it was developed. Care must be taken in using this classification in other watersheds. More work is required in classifying winter salmonid habitat in other watersheds and in comparing it to habitat characterized in this paper.

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## APPENDIX 1

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TABLE A1. Description of flooded areas and over-wintering sites associated with the Carnation Creek flood-plain. All flooding levels are estimates of discharge at "B weir".

| Flooded area | Over-wintering site | Description of formation | Description of hydrologic characteristics |
|---|---|---|---|
| R250 m ($1999\ m^2$) | R250 m ($1992\ m^2$) (non habitat) | An ephemeral swamp, formed in a depression perched above the main-stream water-table. Located within a small basin bordered N and E by valley walls. | Floods from main-stream at >35 $m^3$/sec. Good seepage from upland slopes but no notable outlet. Area subject to early desiccation in spring and low water levels during periods of winter freezing. |
| R750 m ($976\ m^2$) | R750 m ($976\ m^2$) | Ephemeral swamp formed in an old channel, parallels a valley wall for its entire length. | Floods through numerous old channel scars at >7 $m^3$/sec. Only one major source of upland seepage. Confluence is perched and requires >7 $m^3$/sec for access. |
| L1250-1550 m ($4107\ m^2$) | L1400 ($963\ m^2$) (non-habitat) | Series of ephemeral swamps and pools formed in old channel which parallels valley wall. The two sites are separated by a slightly higher section containing numerous small stagnant pools. | Entire area connected and flowing at >18 $m^3$/sec. Numerous small seepages from valley wall. Both sites have separate outlets to main-stream. |
| | L1250 m ($1693\ m^2$) | Small ephemeral pools formed within an old channel. | Diffuse outlet may not permit access until >11 $m^3$/sec. Two deep pools contain stagnant water even in summer. |
| | L1550 m ($1451\ m^2$) | Ephemeral swamp bordering main-stream and a valley wall, formed within an old channel. | Site floods at >9 $m^3$/sec and is in direct path of flood water. Good outlet. |
| L1600 m ($1960\ m^2$) | | A first order tributary, has a definable channel for most of its length. Borders a valley wall. | Tributary can be divided into two sites on the basis of differences in summer water levels. |
| | L1600 m lower ($1144\ m^2$) | Intermittent tributary in lower 350 m of tributary course. Borders valley wall. | Contains isolated pools or flowing water at mouth for entire summer. |
| | L1600 m upper ($816\ m^2$) | Ephemeral tributary, in upper 150 m of tributary course, bordering valley wall. Surface covered with thick layer of logging slash for much of length. | Totally dry in summer, with numerous small seepages in winter. Receives flood waters from both main-stream and from "C weir tributary" at flows >20 $m^3$/sec. |

TABLE A1. (continued)

| Flooded area | Over-wintering site | Description of formation | Description of hydrologic characteristics |
|---|---|---|---|
| R1500 m ($502\ m^2$) | R1500 m ($502\ m^2$) | Small ephmeral swamps formed within two separate old channel scars. Both parallel the valley wall. One channel is fairly recent and has a gravel bottom for much of its length. | Totally dry in summer. Floods at low flows <6 $m^3$/sec, receives high velocity flood waters and provides the least protection for over-wintering coho of all the sites. Outlet periodic during the winter. |
| R2600 m ($3272\ m^2$) | R2600 m lower ($1688\ m^2$) | Intermittent tributary associated with valley wall for its entire course. Channel indistinct in areas of deep muck soils where the main channel diffuses into a network of small channels. | Flows at confluence all summer but various sections lack surface flow. No visual observation of flooding level was made (not observed, but estimated at 23 $m^3$/sec). |
| | R2600 m upper ($777\ m^2$) | Intermittent tributary forms in canyon and flows onto the flood-plain. | Continuous flow throughout the year. Only part of this site can flood from main-stream. |
| | R2600 m ponds ($807\ m^2$) | Series of small ponds formed in a depression within an old abandoned channel. Site flat with no relationship to valley walls. | No upland seepage, depression may receive ground water from tributary. Floods from tributary at >7 $m^3$/sec and floods from the main-stream at an estimated level of >23 $m^3$/sec (flooding never observed as researchers unable to enter area under flooding conditions). |
| Total $12807\ m^2$. | Total $9845\ m^2$ (habitat only). | | |

TABLE A2. Characteristic combinations of plant species, for plant associations located within winter flooded land, on the Carnation Creek flood-plain, 5-10 years after harvest

| Group | Temporary name | Characteristic species | Constant species |
|---|---|---|---|
| Group 1 | Rush | *Scirpus microcarpus*<br>*Juncus ensifolius*<br>*Lecidea sp.* | *Lysichiton americanum*<br>*Oenanthe sarmentosa*<br>*Epilobium (ciliatum?)* |
| Group 2 | Seepage | *Lecidea sp*<br>*Scirpus microcarpus*<br>*Sphagnum sp.*<br>*Agrostis stolonifera*<br>*Maianthemum dilatatum*<br>*Aira sp.*<br>*Rubus spectabilis*<br>*Polythrichum juniperinum*<br>*Juncus effusus*<br>*Anaphalis margaritacea*<br>*Blechnum spicant* | *Athyrium filix-femina*<br>*Lysichiton americanum*<br>*Oenanthe sarmentosa*<br>*Epilobium (ciliatum?)* |
| Group 3 | Grass-meadow | *Sphagnum sp.*<br>*Agrostis stolonifera*<br>*Viola palustris*<br>*Maianthemum dilatatum*<br>*Aira sp.*<br>*Rubus spectabilis*<br>*Polytrichum juniperinum* | *Athyrium filix-femina*<br>*Lysichiton americanum*<br>*Oenanthe sarmentosa*<br>*Epilobium (ciliatum?)* |
| Group 4 | Sedge-meadow | *Galium triflorum*<br>*Carex obnupta*<br>*Fontinalis antipyretica* | *Athyrium filix-femina*<br>*Lysichiton americanum*<br>*Oenanthe sarmentosa*<br>*Epiloboim (ciliatum?)* |

TABLE A3. Grouping of plant communities, within winter flooded land located on the Carnation Creek flood-plain, 5-10 years after harvest, based on vertical spacing of the vegetation

| Grouping | Temporary name | Features characteristic of group |
|---|---|---|
| Group 1 | Bare | <25% C and <10% D |
| Group 2 | Herbs | >70% C and <10% D |
| Group 3 | Herbs and moss | >70% C and >10% D |
| Group 4 | Shrubs present | 25-70% and >5% D and <1% B |

TABLE A4. Grouping of plots within winter flooded land located on the Carnation Creek flood-plain, 5-10 years after harvest, based on percentage of surface covered by woody debris

| Grouping | Temporary name | Features characteristic of group |
|---|---|---|
| Group 1 | Exposed | <90% Woody debris |
| Group 2 | Woody debris | >90% Woody debris |

TABLE A5. Grouping of plots, within winter flooded land located on the Carnation Creek flood-plain, 5-10 years after harvest, based on two soil features (percent organic material by weight and percent of particles <.25 mm)

| Grouping | Temporary name | Features characteristic of group |
|---|---|---|
| Group 1 | Gravel | <5% organic, <10% of soil particles smaller than 0.25 mm |
| Group 2 | Muck | >5% organic, >10% of soil particles smaller than 0.25 mm |

TABLE A6. Grouping of plots within winter flooded land located on the Carnation Creek flood-plain, 5-10 years after harvest, based on mean summer and mean winter water- levels

| Grouping | Temporary name | Features characteristic of group |
|---|---|---|
| Group 1 | Flooded-meadows | >10 cm seasonal change, summer water levels <-25 cm |
| Group 2 | Muck-swamps | >10 cm seasonal change, summer water levels >-25 cm |
| Group 3 | Constant-seepage | <10 cm seasonal change, water levels fall below 8 cm |
| Group 4 | Exposed gravel | <10 cm seasonal change, water levels remain above 8 cm |

TABLE A7. Summary of discriminant groupings used to delineate map units located within winter flooded land on the Carnation Creek flood-plain

| | Discriminative factor grouping | | | | |
|---|---|---|---|---|---|
| Map unit | Plant association | Vegetation stratum | Debris | Soil | Water level |
| Unit 1 | 1. | 1. | 1. | 1. | 4. |
| Unit 2 | 1. | 1. | 1. | 2. | 2. |
| Unit 3 | 1. | 2. | 1. | 2. | 2. |
| Unit 4 | 2. | 4. | 1. | 2. | 3. |
| Unit 5 | 3. | 4. | 1. | 2. | 1. |
| Unit 6 | 4. | 3. | 1. | 2. | 1. |
| Unit 7 | - | - | 2. | - | - |

TABLE A8. Description of map units located within winter flooded land on the Carnation Creek floodplain. Plant constants include: *Lysichiton americanum* , *Oenanthe sarmentosa* , and *Epilobium..sp.*

| Map unit | Name | Description |
|---|---|---|
| Unit 1 | Exposed gravel | Vegetation covers <25% of surface, dominated by *Oenanthe sarmentosa* and isolated *Scirpus microcarpus*. Surface consists of gravels and coarse sands washed clean of fine organic material.Water levels are constant throughout the year and standing water is always present. |
| Unit 2 | Exposed muck | Vegetation covers <25% of surface, dominated by *Oenanthe sarmentosa* , *Zannichellia palustris* , and isolated *Scirpus microcarpus*. Surface consists of an organic muck blanket. Water levels are seasonally variable but are always within 25 cm of the surface; thus, through capillary rise, the surface may appear wet even in summer. |
| Unit 3 | Bullrush-cattail | Vegetation covers >70% of surface, dominated by thick beds of *Scirpus microcarpus* and *Juncus ensifolius*. Other species often present include *Lecidea sp.*, *Typha latifolia* , and *Scutellaria lateriflora*. Shrub and moss layers absent or poorly developed. Water levels similar to map unit 2. |
| Unit 4 | Juncus-seepage | Vegetation covers 25-70% of surface and, as the surface may be micromounded, considerable variation in water levels and plant species may result. Plant species such as *Juncus effusus* , *Maianthemum dilatatum* , *Agrostis stolonifera* , *Anaphalis margaritacea* , and *Blechnum spicant* dominate while the wettest pockets may contain isolated *Scirpus microcarpus* and the driest mounds may support grouth of*Rubus spectabilis*. *Sphagnum sp.* is always present. Water levels are constantly at or near the surface. |
| Unit 5 | Sedge-meadow | Surface covered by thick beds (>70%) of *Carex obnupta* and the moss *Fontinalis antipyretica*. *Galium triflorum* and *Athyrium filix-femina* may be present. Water levels are highly variable, sites are often flooded to depths >40 cm in winter and dry (<-60 cm) in summer. Surface soil is organic muck. |
| Unit 6 | Grass-meadow | Surface covered (25-70%) by grasses (*Aira sp.* and *Agrostis stolonifera* ), herbs (*Maianthemum dilatatum* and *Viola palustris* ):, mosses (*Sphagnum sp.* and *Polytrichum juniperinum* ), and by isolated shrubs (*Rubus spectabilis* ) levels and soil similar to map unit 5. |
| Unit 7 | Woody debris | Surface covered by >90% woody debris. This map unit may overlie all other mapping units, preventing their delineation. |

TABLE A9. Description of salmonid habitat units located on the Carnation Creek flood-plain

| Habitat unit | Name | Description |
|---|---|---|
| Unit 1 | Intermittent tributaries (coho and trout winter and summer habitat) | Described by map unit 1. Subject to water velocities capable of scouring away fine materials and rooted vegetation. Surface consists of exposed gravel and sand. Supports both coho and trout for the entire year. |
| Unit 2 | Ephemeral swamps (coho winter habitat) | Described by map unit 2 and 3. Summer water levels are near the surface (>-25 cm) and winter water level is adequate to support juvenile coho. Trout do not use this habitat. Surface consists of an organic muck blanket. Plants characteristic of this unit include *Scirpus microcarpus* , *Juncus ensifolius* , and *Zannichellia palustris* . Shrubs and mosses are generally absent. |
| Unit 3 | Seepage sites and flooded meadows (non-habitat) | Described by map unit 4, 5, and 6. Although water levels are meadows (non-habitat)highly variable, these map units lack a water level adequate to maintain a fish population over the winter period. Coho may move across this unit during winter floods. Surface consists of an organic muck layer similar to habitat unit 2.Vegetation tends towards sedges, grasses, and isolated shrubs. A well-developed moss layer may be present. |

TABLE A10. Areas of habitat units and salmonid population estimates for 11 locations on the Carnation Creek flood-plain (nine over-wintering sites and two non-habitat sites)

| | Habitat unit areas ($m^2$) | | | | Population estimates[a] | |
|---|---|---|---|---|---|---|
| Location | 1 | 2 | 3 | Total | Coho | Trout |
| R250 m | 0 | 0 | 1999 | 1999 | 0 | 0 |
| R750 m | 0 | 731 | 246 | 977 | 231 | 3 |
| R1500 m | 0 | 319 | 183 | 502 | 110 | 0 |
| L1250 m | 0 | 554 | 1139 | 1693 | 63 | 1 |
| L1400 m | 0 | 52 | 911 | 963 | 2 | 0 |
| L1550 m | 0 | 893 | 558 | 1451 | 253 | 2 |
| L1600 m lower | 407 | 403 | 334 | 1144 | 316 | 120 |
| L1600 m upper | 46 | 409 | 361 | 816 | 183 | 1 |
| R2600 m lower | 250 | 361 | 1113 | 1724 | 270 | 103 |
| R2600 m upper | 185 | 276 | 316 | 777 | 91 | 62 |
| R2600 m ponds | 0 | 241 | 566 | 807 | 66 | 3 |
| Total | 888 | 4239 | 7726 | 12853 | 1585 | 295 |

[a]Population estimates represent the average of two winters.

TABLE A11. Vegetation species list and codes used in vegetation table

| | | |
|---|---|---|
| 1 | ADIAPED | Adiantum pedatum |
| 2 | AGROSTO | Agrostis stolonifera |
| 3 | AIRA | Aira sp |
| 4 | ALNURUB | Alnus rubra |
| 5 | ANAPMAR | Anaphalis margaritacea |
| 6 | ARUNCUS | Aruncus sp |
| 7 | ATHYFIL | Athyrium filix-femina |
| 8 | BLECSPI | Blechnum spicant |
| 9 | CAREFLA | Carex flava |
| 10 | CARELIV | Carex livida |
| 11 | CAREMER | Carex mertensii |
| 12 | CAREOBN | Carex obnupta |
| 13 | CLAYSIB | Claytonia sibirica |
| 14 | DISPTRA | Disporum trachycarpum |
| 15 | ELEOPAL | Eleocharis palustris |
| 16 | EPILANG | Epilobium angustifolium |
| 17 | EPILCIL | Epilobium ciliatum |
| 18 | EQUIPAL | Equisetum palustre |
| 19 | FONTANT | Fontinalis antipyretica |
| 20 | GALITRF | Galium triflorum |
| 21 | GEUMMAC | Geum macrophyllum |
| 22 | HERASPH | Heracleum sphondylium |
| 23 | HYLOSPL | Hylocomium splendens |
| 24 | HYPORAD | Hypochoeris radicata |
| 25 | JUNCEFF | Juncus effusus |
| 26 | JUNCENS | Juncus ensifolius |
| 27 | JUNCUS | Juncus sp |
| 28 | LACTUCA | Lactuca sp |
| 29 | LECIDEA | Lecidea sp |
| 30 | LUZUPAR | Luzula parviflora |
| 31 | LYSIAME | Lysichiton americanum |
| 32 | MAIADIL | Maianthemum dilatatum |
| 33 | MALUFUS | Malus fusca |
| 34 | MENZFER | Menziesia ferruginea |
| 35 | MITEPEN | Mitella pentandra |
| 36 | MNIUGLA | Mnium glabrescens |
| 37 | MNIUINS | Mnium insigne |
| 38 | OENASAR | Oenanthe sarmentosa |
| 39 | OSMORHI | Osmorhiza sp |
| 40 | PELTIGE | Peltigera sp |
| 41 | PETAFRI | Petasites frigidus |
| 42 | PICESIT | Picea sitchensis |
| 43 | POLYJUN | Polytrichum juniperinum |
| 44 | POLYMUN | Polystichum munitum |
| 45 | PRUNVUL | Prunella vulgaris |
| 46 | RIBESAN | Ribes sanguineum |
| 47 | RICCNAT | Ricciocarpos natans |
| 48 | RORIPPA | Rorippa sp |
| 49 | RUBUPAR | Rubus parviflorus |
| 50 | RUBUSPE | Rubus spectabilis |
| 51 | SALILAS | Salix lasiandra |
| 52 | SALISIT | Salix sitchensis |
| 53 | SAMBRAC | Sambucus racemosa |
| 54 | SCIRMIC | Scirpus microcarpus |
| 55 | SCUTLAT | Scutellaria lateriflora |
| 56 | SPARAME | Sparganium americanum |
| 57 | SPHAGNU | Sphagnum sp |
| 58 | SPIRDOU | Spiraea douglasii |
| 59 | STACCOO | Stachys cooleyae |
| 60 | THUJPLI | Thuja plicata |
| 61 | TIARTRI | Tiarella trifoliata |
| 62 | TIARUNI | Tiarella unifoliata |
| 63 | TSUGHET | Tsuga heterophylla |
| 64 | TYPHLAT | Typha latifolia |
| 65 | VACCOVA | Vaccinium ovalifolium |
| 66 | VACCPAR | Vaccinium parvifolium |
| 67 | VEROAME | Veronica americana |
| 68 | VIOLPAL | Viola palustris |
| 69 | ZANNPAL | Zannichellia palustris |

TABLE 12. Significance of plant species per plot (Domin - Krajuna cover abundance scale; Mueller - Dombois and Ellenburg 1974, p.62)

| ST | SPECIES | PRES | PLOTS | | |

# APPENDIX 2

**FIGURES**


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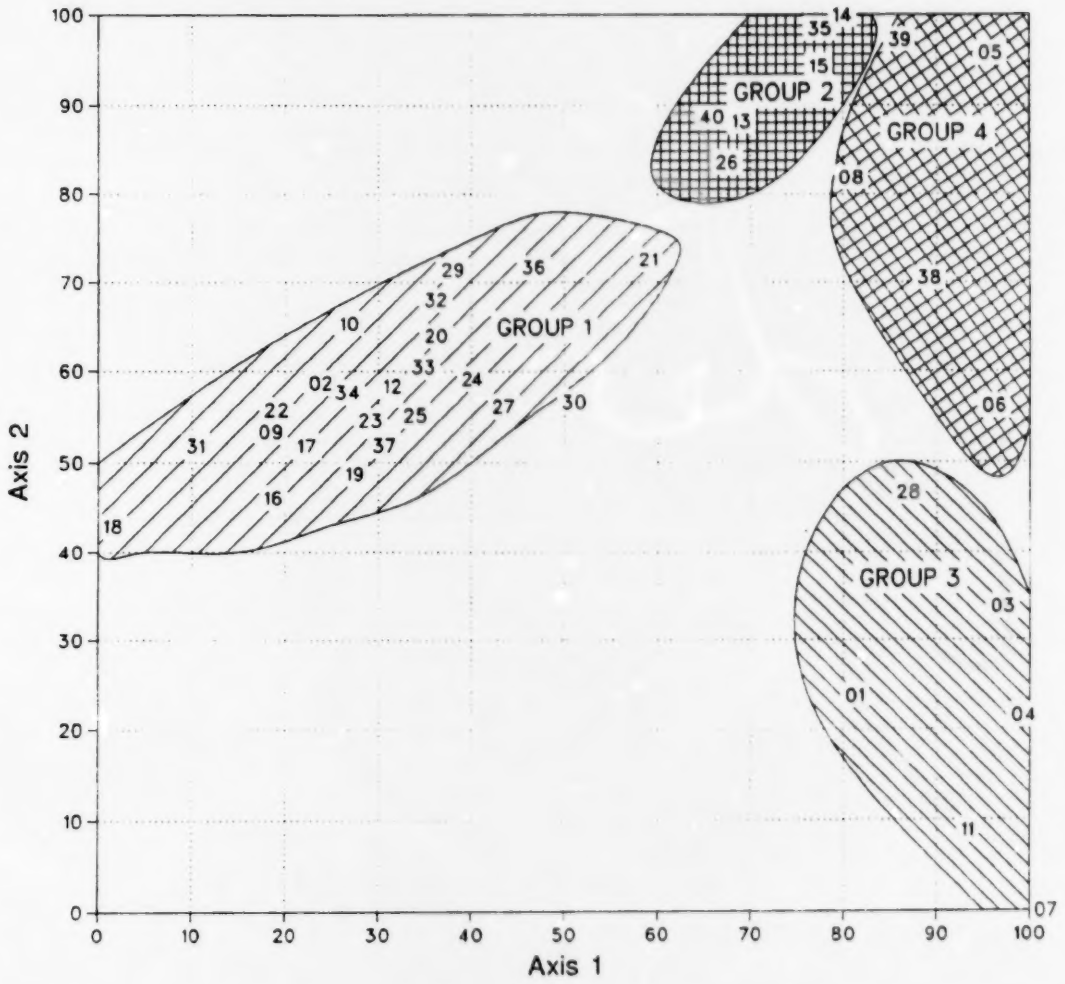



FIGURE A1. Plant associations identified by reciprocal averaging ordination using "Ordiflex" (Gauch 1977). All sample plots are located on the Carnation Creek flood-plain within winter flooded lands.

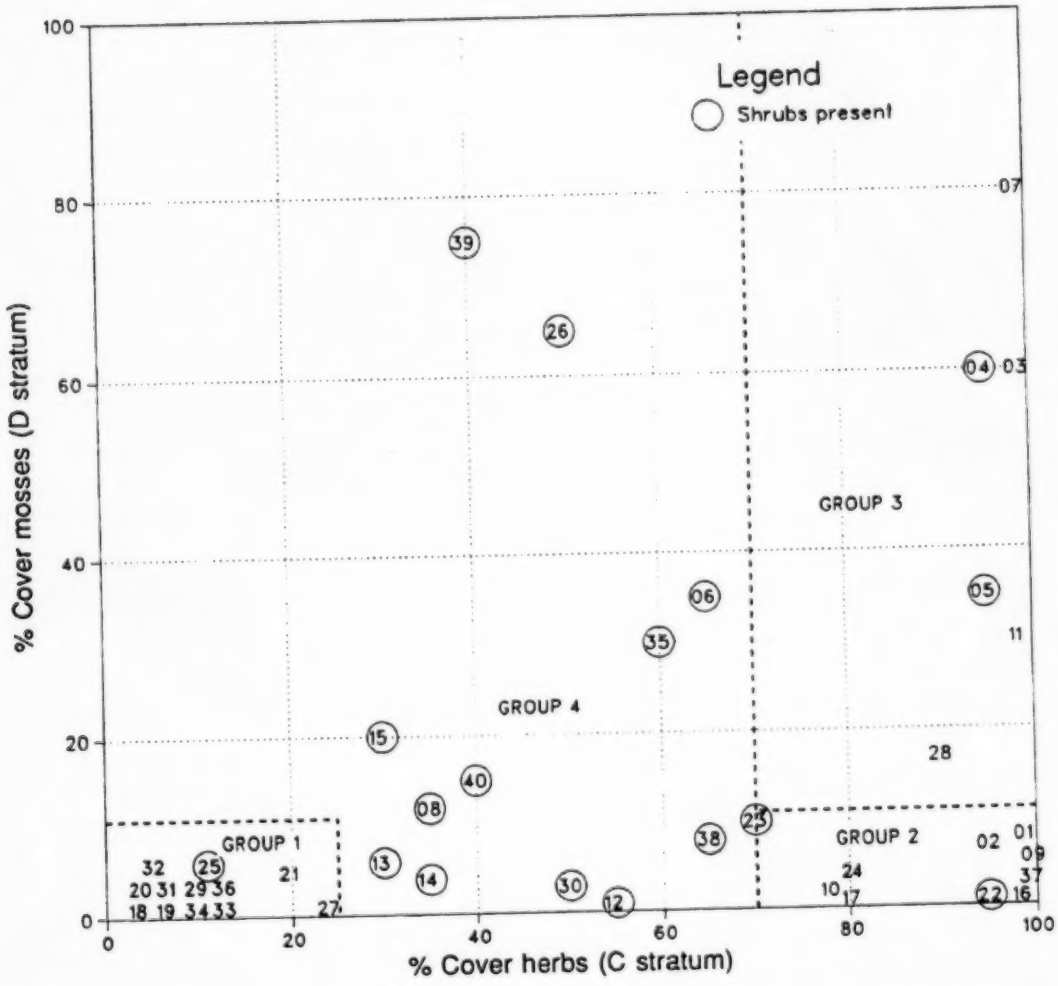



FIGURE A2. Groupings of sample plots by percentage cover per stratum (moss and herb layers). Plots containing shrubs are also indicated. All sample plots are located on the Carnation Creek flood-plain within sites flooded during winter.

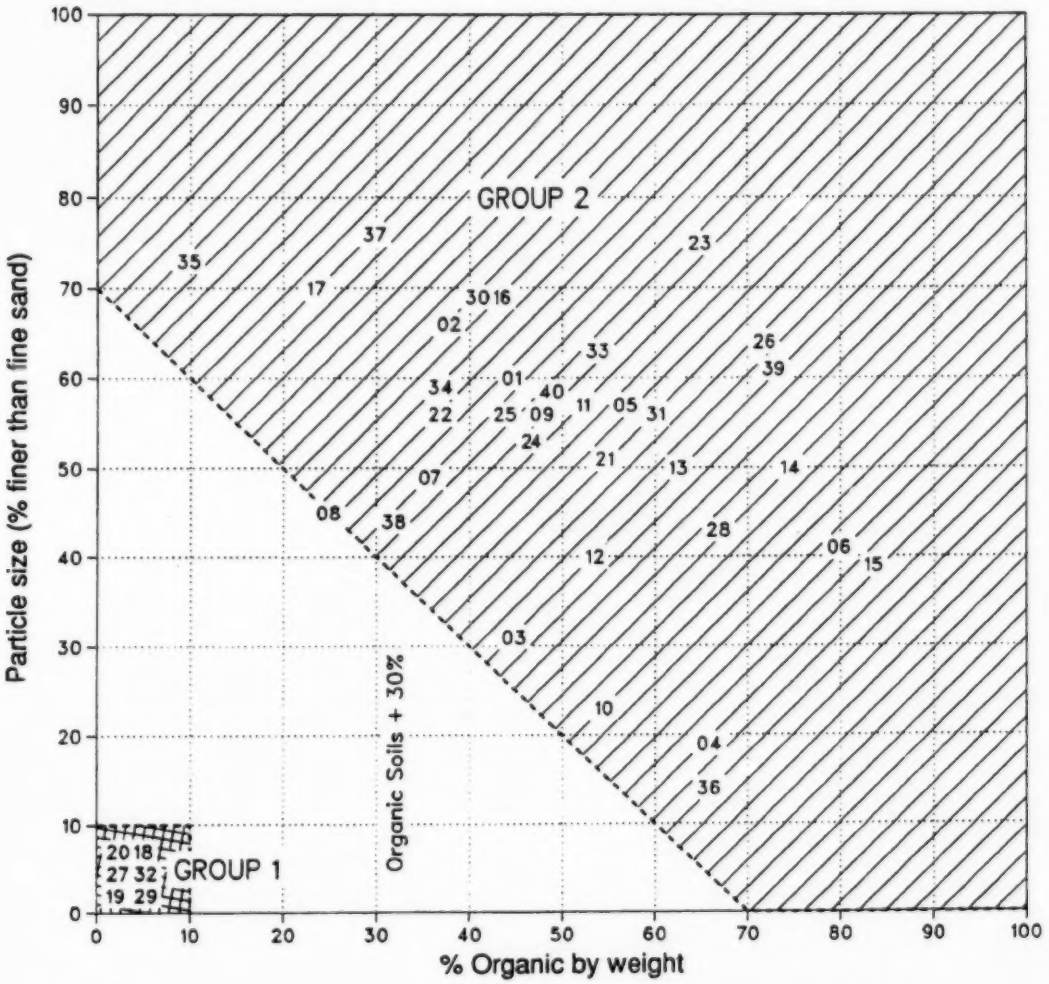



FIGURE A3. Groupings of sample plots by surface soil characteristics (particle size and percent weight loss during ashing). All sample plots located on the Carnation Creek flood-plain within sites flooded during winter.

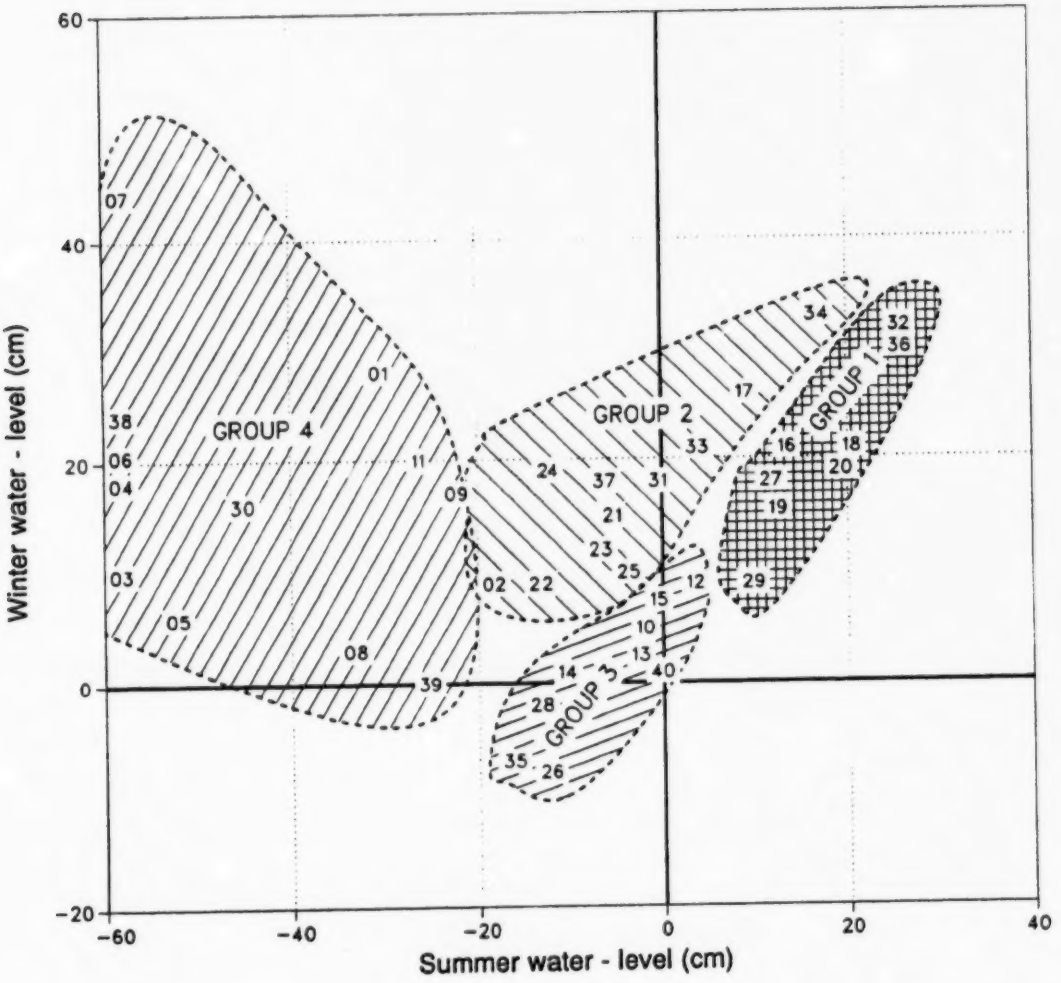



FIGURE A4. Groupings of plots located on the Carnation Creek flood-plain by mean seasonal water-levels (summer and winter) relative to plot surface.

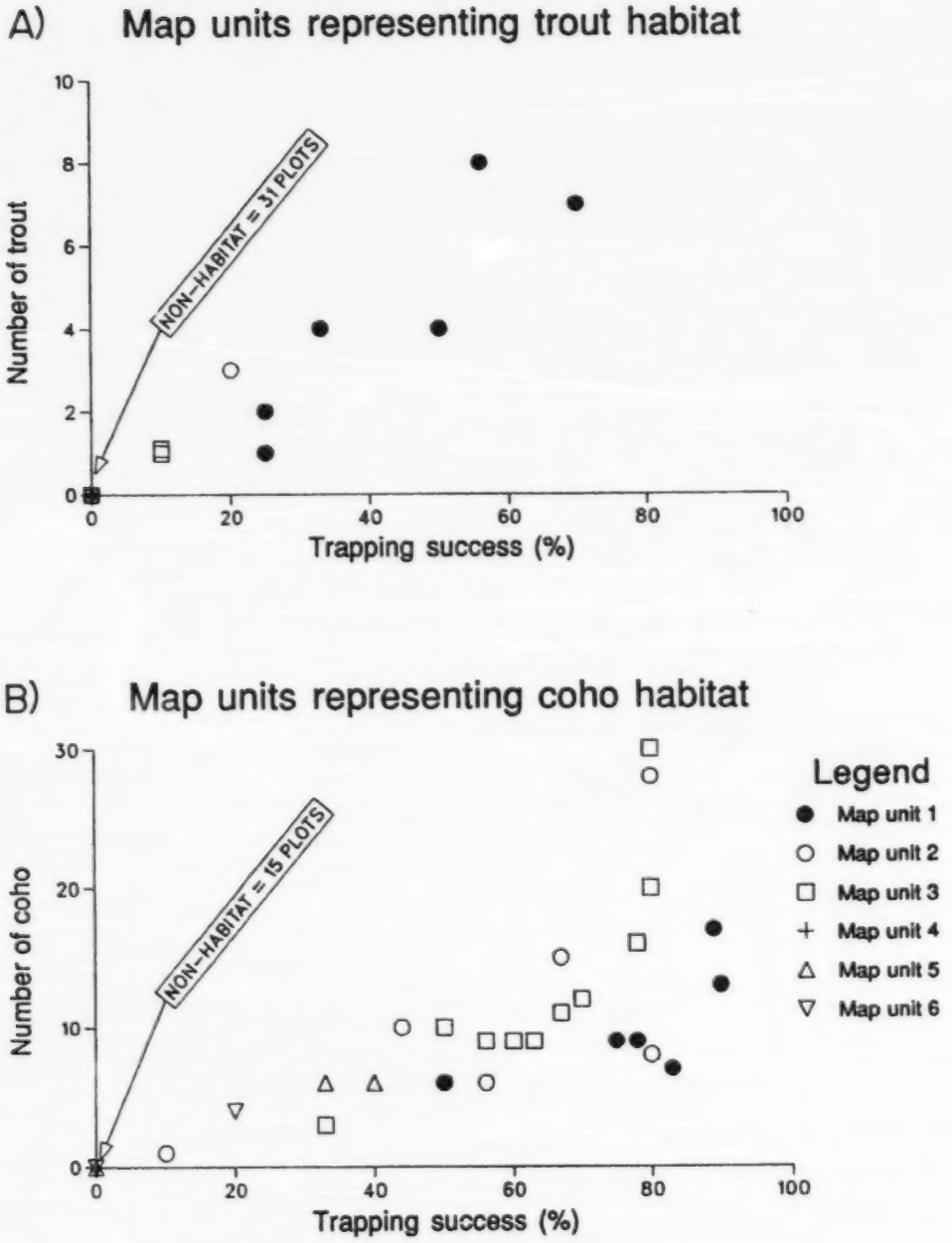



FIGURE A5. Relative success by sample plot (total number of fish captured and percent of sampling dates on which fish were captured) for: A) "trout"; and B) coho.

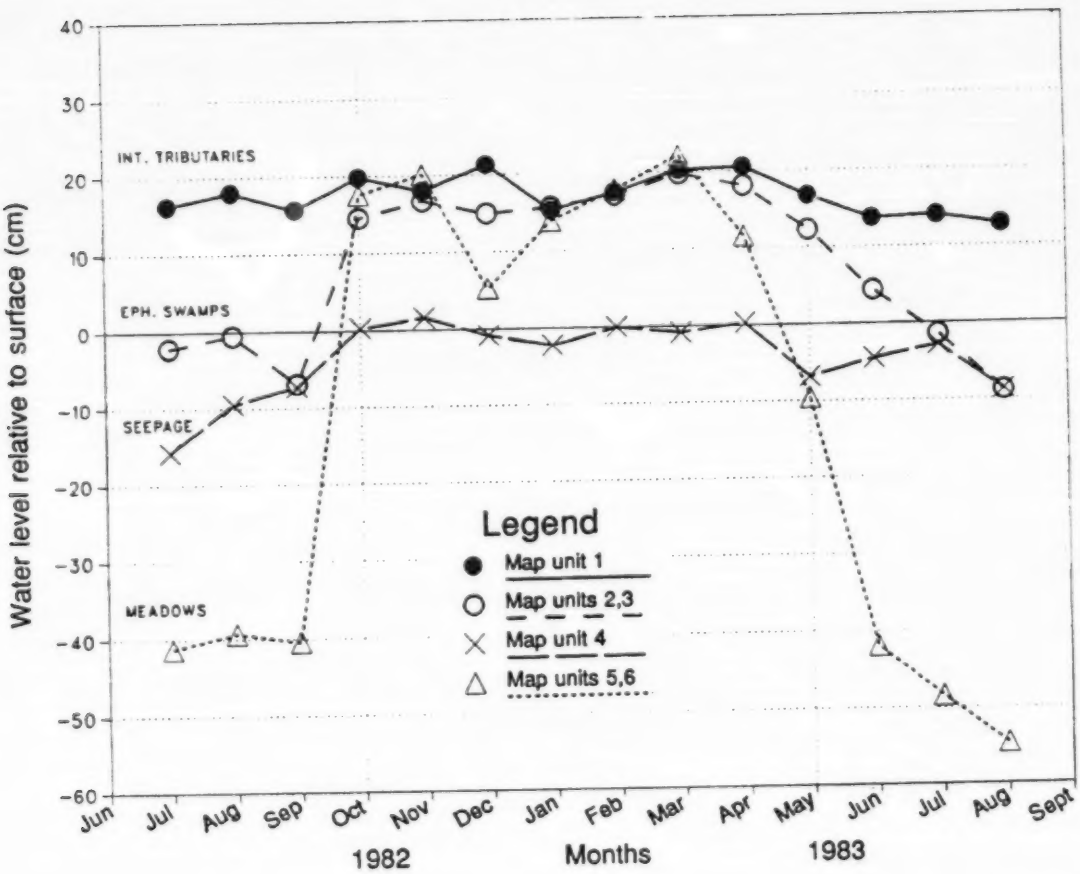



FIGURE A6. Monthly water level (relative to the surface) for mapping units representing: intermittent tributaries (1), ephemeral muck swamps (2 and 3), seepage sites (4), and flooded meadows (5 and 6).

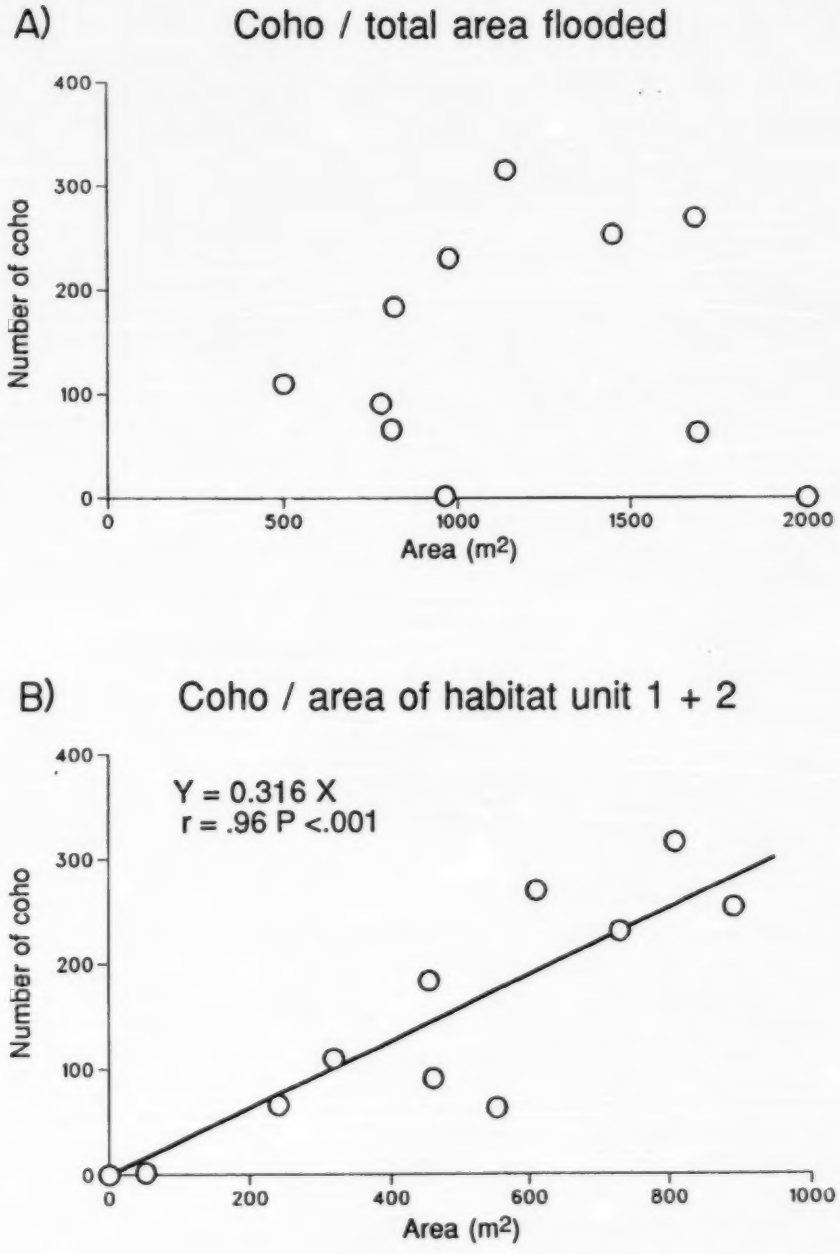



FIGURE A7. The relationship between number of juvenile coho (*Oncorhynchus Kisutch*) and two area estimations: A) total flooded area; and B) coho winter habitat (habitat units 1 and 2).

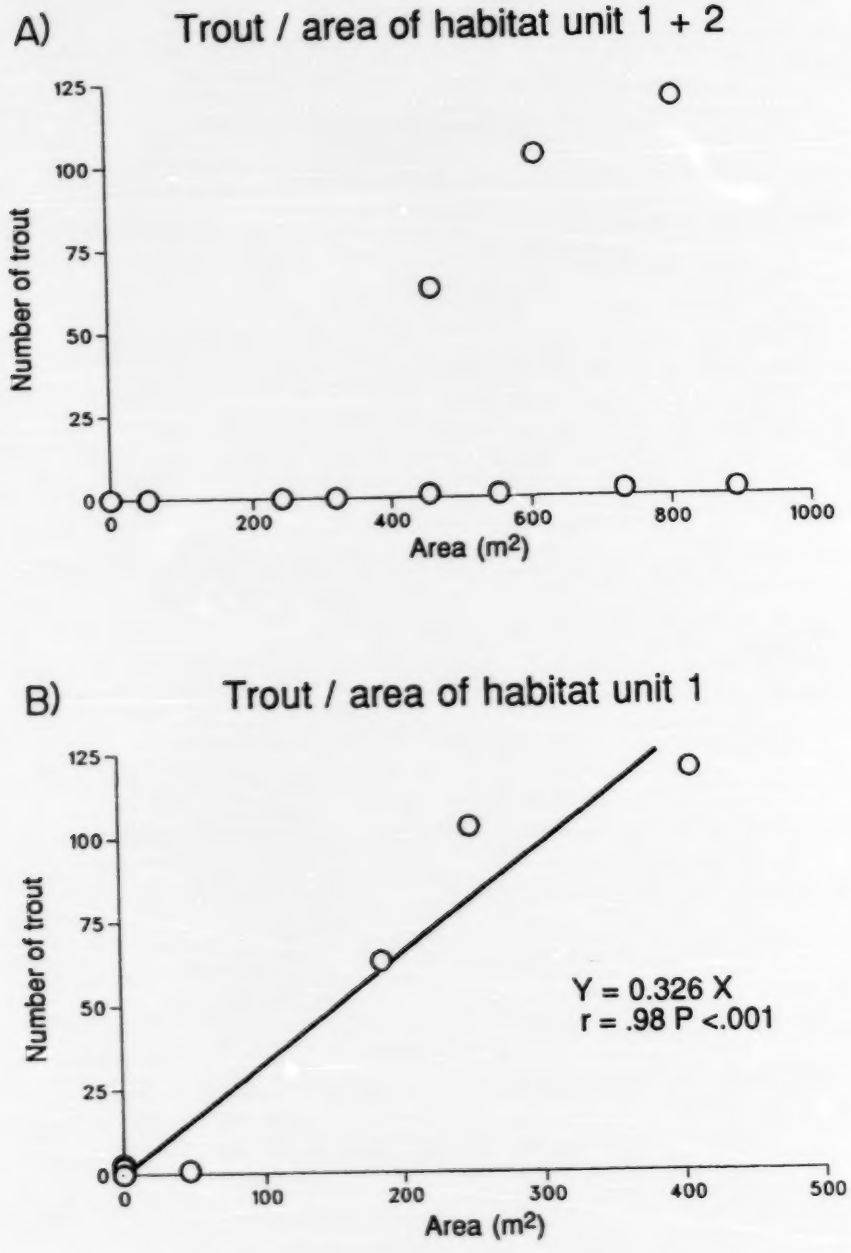
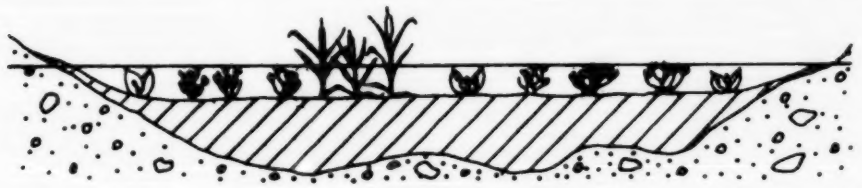


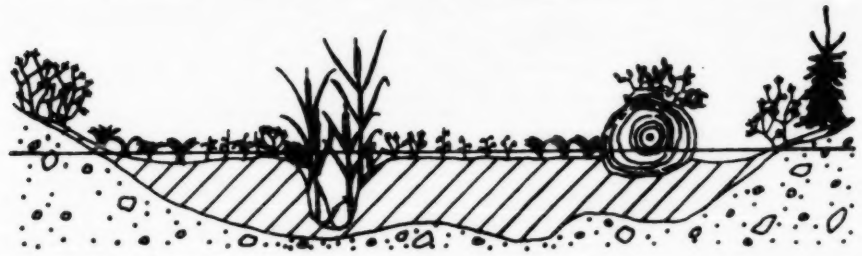

FIGURE A8. The relationship between number of juvenile "trout" and two area estimations: A) area designated as coho winter habitat (habitat unit 1 and 2); and B) area designated as trout winter habitat (habitat unit 1).

b) a muck pool holds water and supports over-wintering salmonids

a) within an abandoned channel, deposited vertical accretions are held by plants



c) a deep narrow channel forms within a muck blanket (good habitat)



d) shrub and tree growth or possible sedge meadow after fill-in

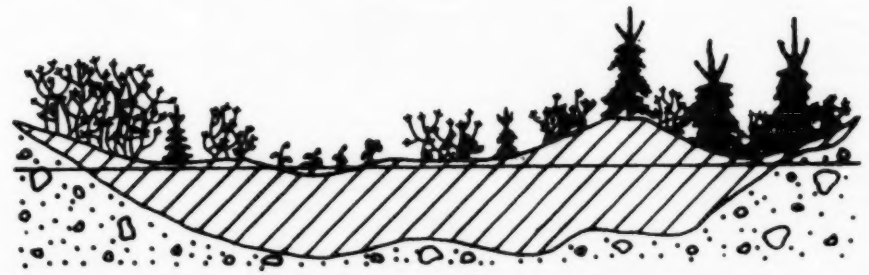


FIGURE A9. Possible succession of coho (*Oncorhynchus kisutch*) off-stream ephemeral over-wintering habitat on an alluvial flood-plain.

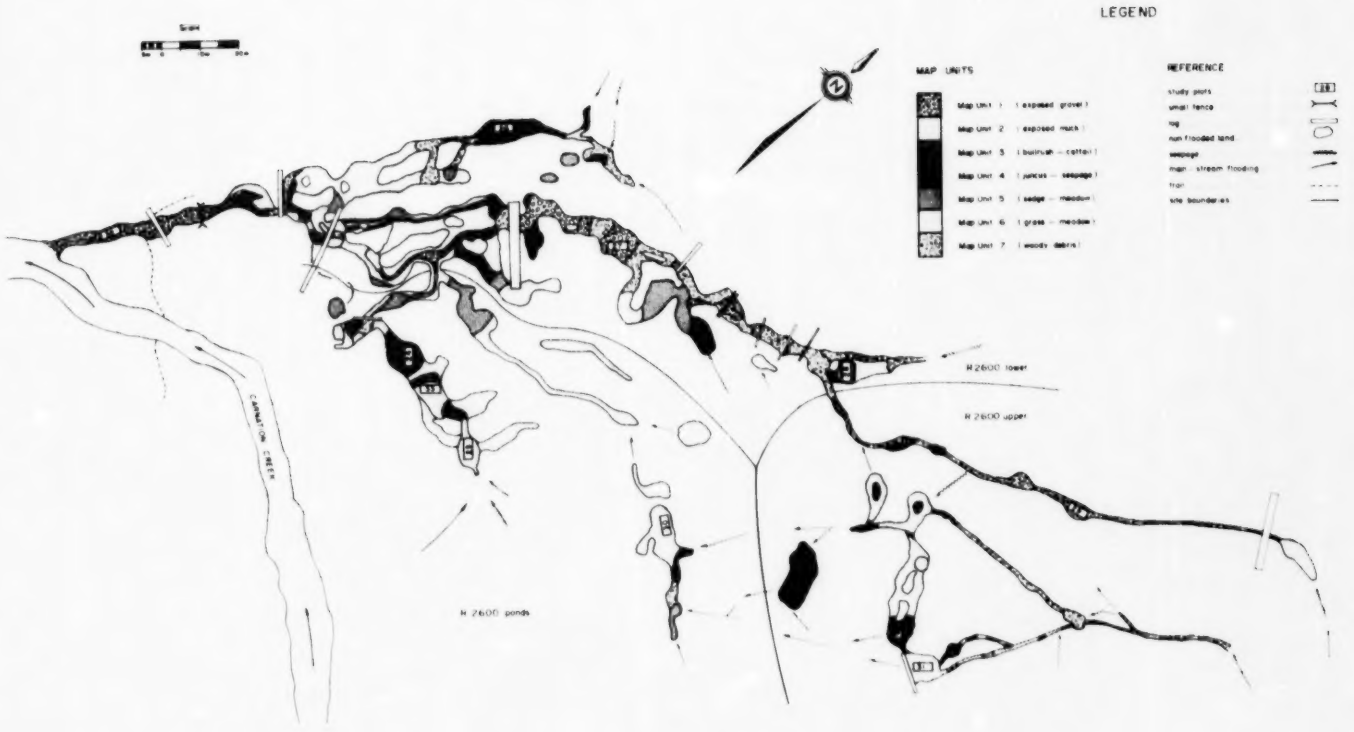



FIGURE A10. Tributary System R 2600.

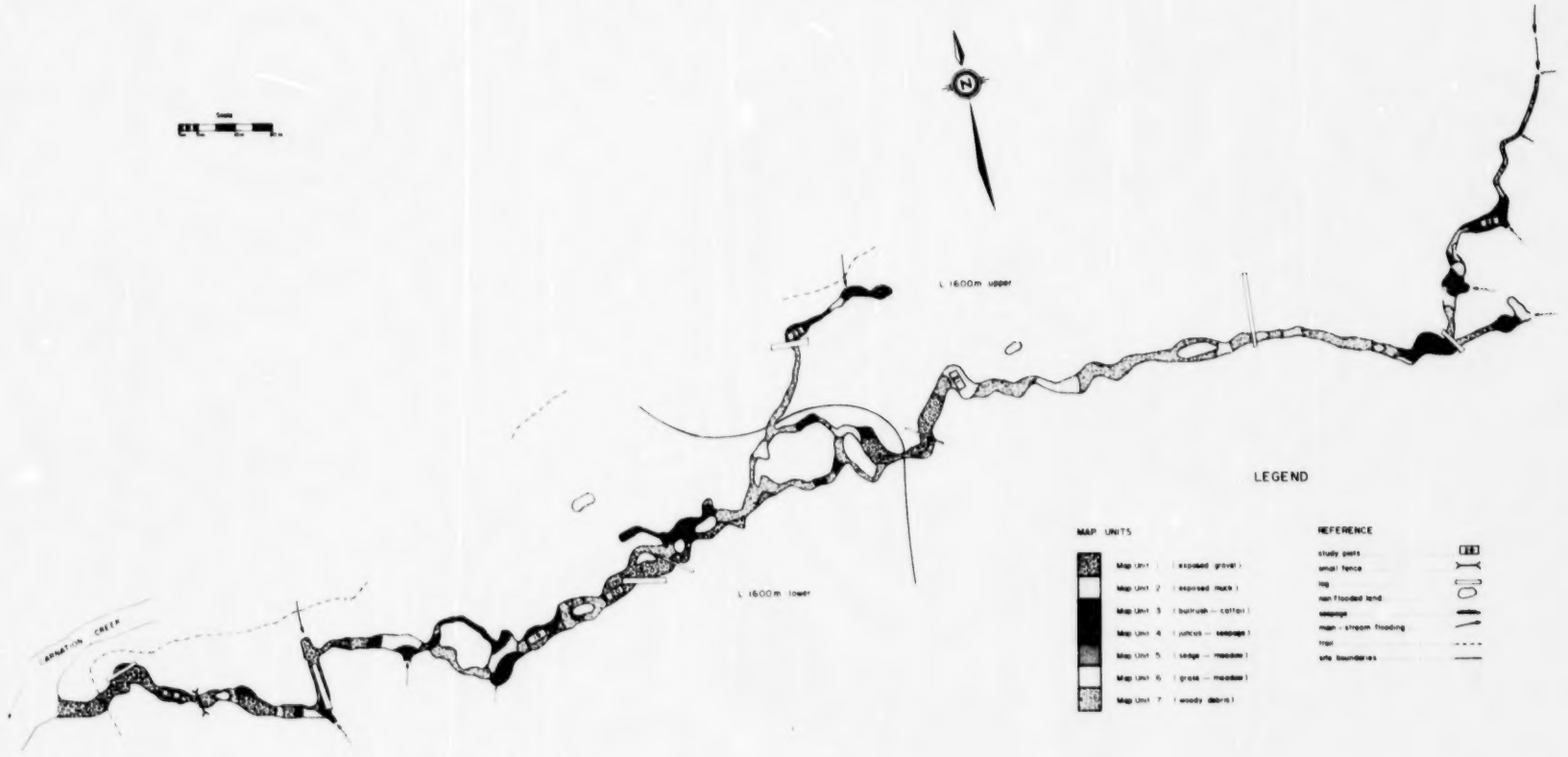



FIGURE A11. Tributary System L 1600.

FIGURE A12. Swamp System L1250 - R 1550.

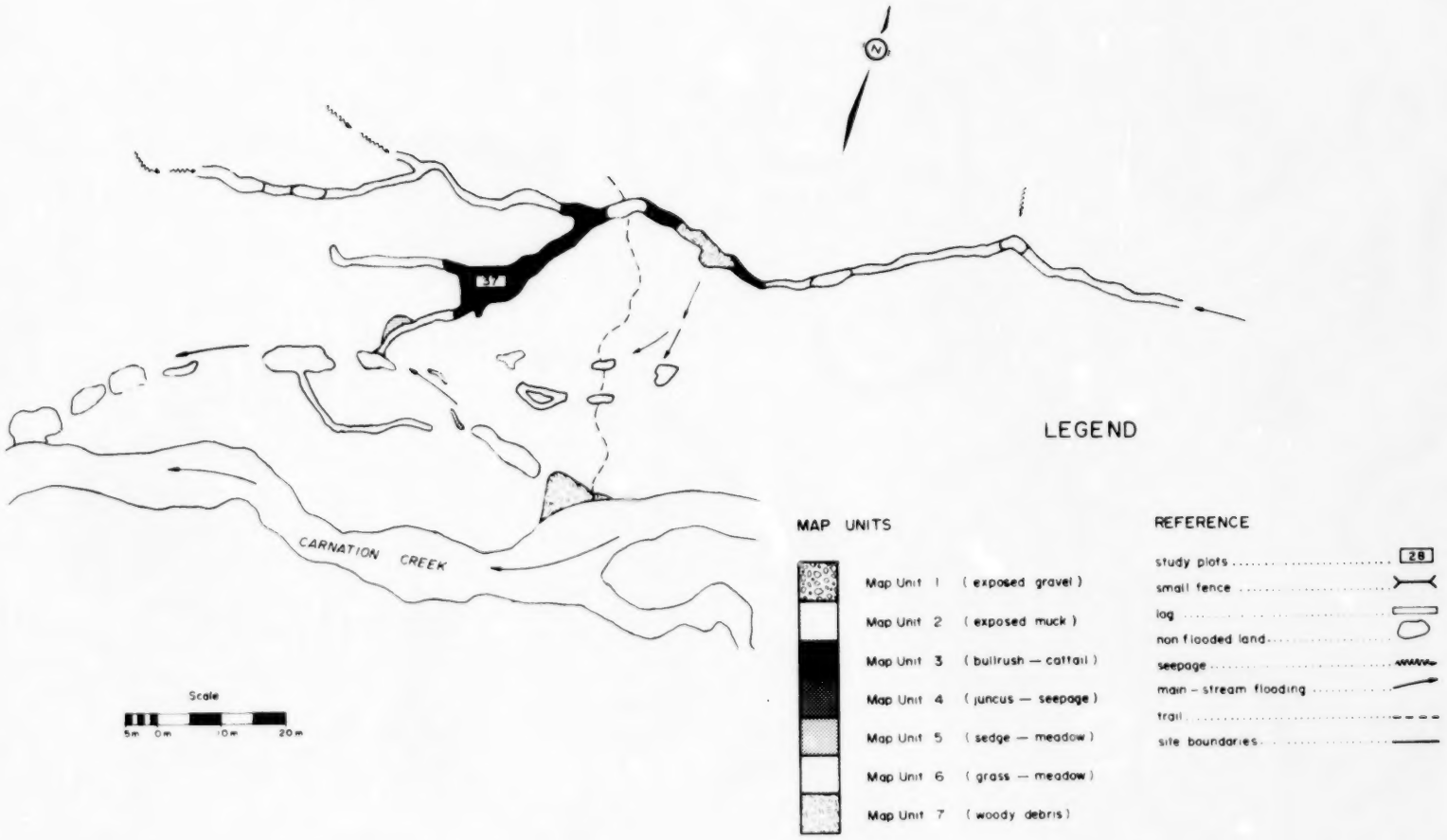



FIGURE A13. Swamp System R 1500.

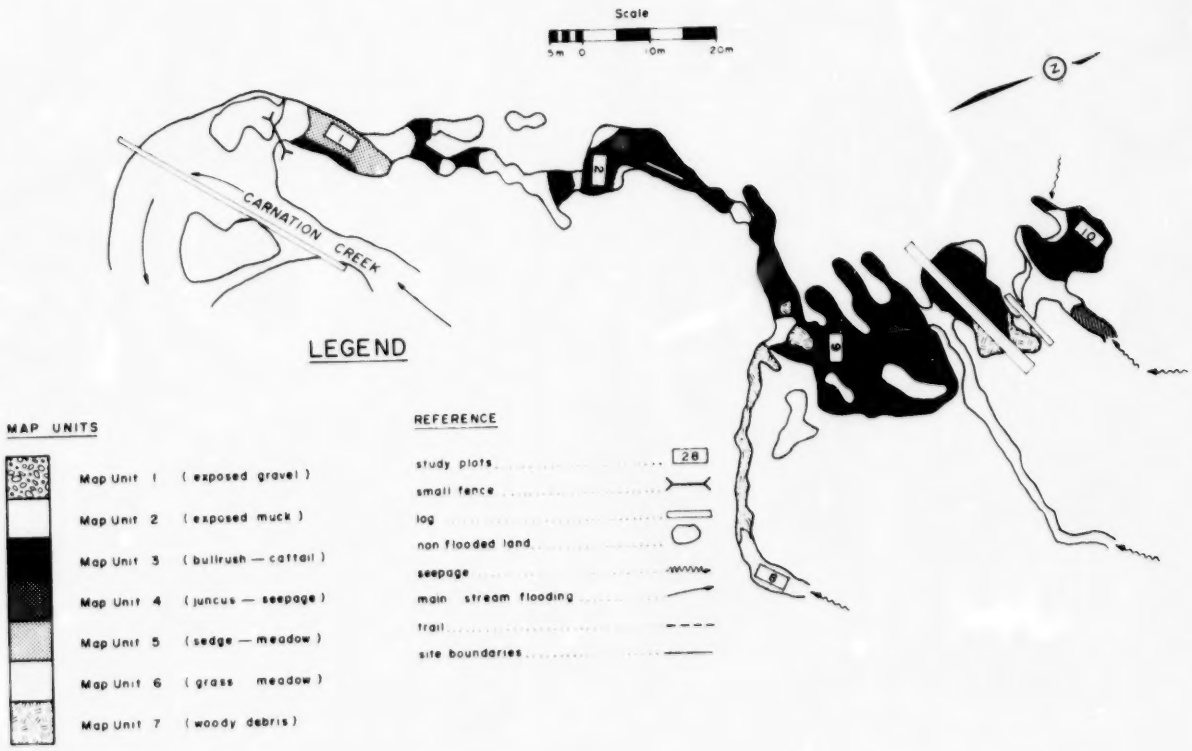



FIGURE A14. Swamp System R 750.

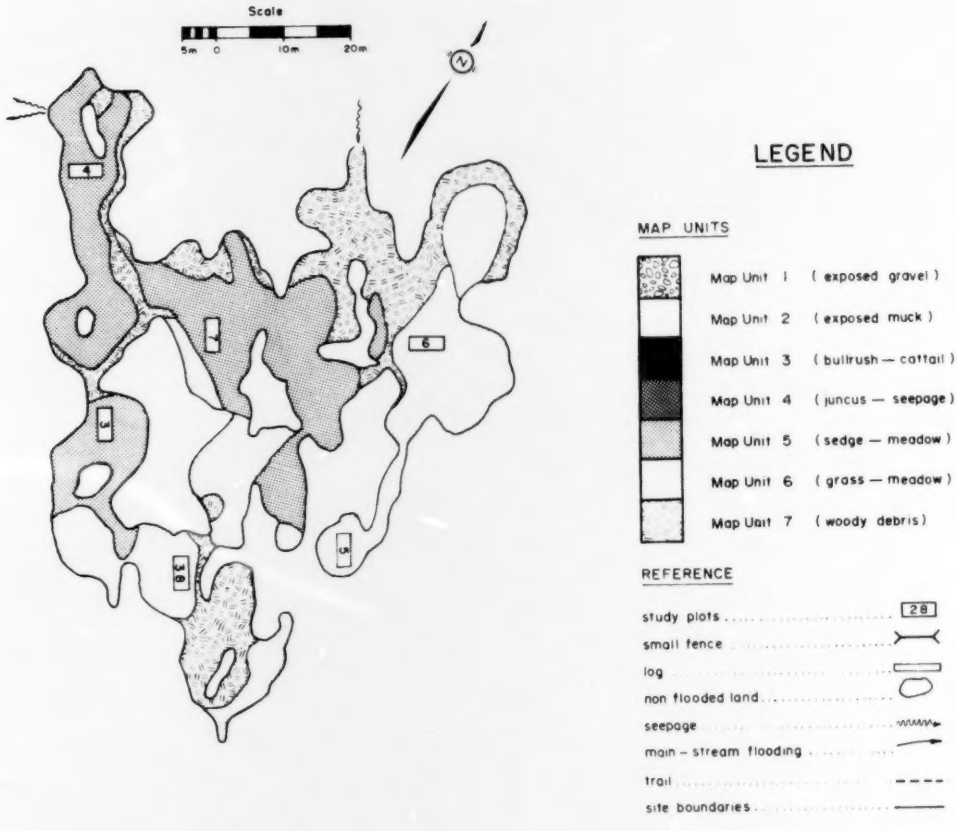



FIGURE A15. Swamp System R 250.